ARRANGEMENT OF THE TISSUES BY WHICH THE COW'S UDDER IS SUSPENDED [1]

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INTRODUCTION

The broken-down, pendulous udder is a defect that occurs frequently among high-producing dairy cows. There are a number of different types of broken-down udders. Some become detached from the body wall, so that the hand can be inserted between the abdomen and the upper surface of the front quarters. Some become elongated vertically like a sack and have a tendency to swing from side to side as the cow walks. In some the median support appears to undergo a relaxation, permitting the floor of the udder to sag and causing the teats to point outward from the sides of the udder. In others the rear attachment appears to become lax, allowing the udder to swing forward, and sometimes causing the rear quarters to occupy a position lower than the front quarters. These are the more common types of broken-down udders; there are many variations.

Generally, this breaking down is a condition that occurs with large, heavy udders. Usually it becomes progressively more pronounced with advance in age. Occasionally it occurs with udders of moderate size and may be pronounced early in life.

The breaking down of udders is frequently attributed to heavy milk production. The physiological function of milk secretion has been developed by breeding and improved nutrition until it has reached amazingly high levels. The range cow produces only enough milk to raise her calf. The good dairy cow produces in 1 year an amount of milk that is equivalent to 8 to 12 times her live weight. In some cases cows have produced an amount of milk in 1 year that was equivalent to 20 times their live weight. The combined weight of the udder and the milk that it contains is often very great.

The broken-down or pendulous udder is objectionable for a number of reasons. Such udders are difficult to milk; they are hard to keep clean; they interfere with the cow's locomotion; they are subject to friction, trauma, and injuries from sharp objects; and the teats are often injured as a result of being stepped on by the cow herself or by cows in adjoining stalls. Moreover, such udders are unsightly. Good-producing cows that have pendulous udders have much lower sale value than cows with well-attached udders, although little is known of the effect of this condition on the animal's producing ability. In view of the greater liability of the pendulous udder to injury such an udder would appear to be more subject to mastitis.

A more comprehensive knowledge of the supporting tissues of the udder may suggest methods of management that will be helpful in preventing broken-down udders; it may suggest points to be consid-

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ered in the selection of cows that are less likely to be susceptible to this trouble; or it may suggest points to be considered in the selection of animals for a breeding program having for its objective the fixing of an inheritance for strongly supported udders. With these facts in mind a study was undertaken to determine the nature of the structures that support and maintain the udder in well-balanced suspension. The results of the study are presented in this paper.

REVIEW OF LITERATURE

A recent tabulation of the weights (after milking) of excised udders of cows that were slaughtered by the Bureau of Dairy Industry, in connection with its studies of conformation and anatomy in relation to producing capacity at Beltsville, Md., gives some idea of the size of the udder of high-producing dairy cows.[2] Data were available for 50 lactating Holstein-Friesian cows 4 years of age or over. On an average the weight of the udder declined with advance in the stage of lactation. The udders of 17 cows that had been milked 3 months or less in the current lactation at the time of slaughter averaged 72.98 pounds; those of 25 that had lactated 6 months or less averaged 65.07 pounds; those of 35 that had been milked 9 months or less averaged 58.08 pounds; those of 41 that had been in milk for 12 months or less averaged 55.89 pounds; and the entire group of 50 udders had an average empty weight of 52.47 pounds. Among these there was 1 that weighed 165.65 pounds, which was approximately 11 percent of the live weight of the cow; and 2 others that weighed 138.20 and 101.85 pounds, respectively.

The results of a number of investigations indicate the weights of blood and milk that the udder may carry.

Swett, Miller, and Graves (*8*)[3] found that a large proportion of the milk obtained at a milking is stored in the udder before the milking process is commenced. Thus a heavy-milking cow producing 100 pounds of milk on twice-a-day milking might have 50 pounds or more of milk in the udder before each milking.

Shaw and Petersen (*6*) found that for each pound of milk secreted, nearly 400 pounds of blood passes through the udder. This means that for a cow producing 100 pounds of milk daily, the blood passing through the udder in that length of time would amount to approximately 40,000 pounds. The total quantity of blood in the body of a lactating cow has been determined (*2, pp. 54–55*) to be approximately 8 percent of the cow's live weight. This means that the bodies of few cows would contain more than 150 pounds of blood. Presumably only a small proportion of the total amount of blood would be present in the udder at any time. According to Kay (*5*) the udder in full lactation takes about one-quarter of the heart's output of arterial blood.

Thus the total weight of the milk and blood in the udder at any time might easily be 50 to 60 pounds, but probably would not exceed 75 pounds, except in unusual cases. This would mean that the total weight of a large, heavy-producing udder, together with its contents, might vary between limits of approximately 100 to 250 pounds. In view of the great weight of the functioning udder and its contents it is

[2] Unpublished data.

[3] Italic numbers in parentheses refer to Literature Cited, p. 43.

not surprising that in many cases the anatomical structures by which the udder is suspended are inadequate to support it in its proper position.

There are some indications that the tendency for the udder to break away from its attachments is inherited. It appears to occur with high frequency among the daughters of certain sires.

The weakness may result from poor tonus in the supporting structures. According to Hammond (*4*) the formation of pendulous udders is the result of excessive and continued internal pressure produced by the accumulated milk in the udder.

Some believe that a weakness in the support of the udder causes faulty circulation which tends to produce stasis, edema, fibrosis, and an increase in the size and weight of the udder. This in turn would further stimulate the breaking-down process and make the abnormalities resulting from faulty circulation even more pronounced.

Sisson (*7, p. 620*) describes the suspensory apparatus as follows:

> The mammary glands, normally two in number, are popularly termed the udder. They are very much larger than in the mare, and the body of each is somewhat ellipsoidal in form, but flattened transversely. The base of each gland is slightly concave and slopes obliquely downward and forward in adaptation to the abdominal wall, to which it is attached by means of a well-developed suspensory apparatus (Lig. suspensorium mammaricum) which extends backward and is attached to the symphysis pelvis by means of the strong plate of tendinous tissue (Tendo subpelvina). This plate of tissue attaches the prepubic tendon to the ventral part of the symphysis. The suspensory apparatus consists essentially of four sheets of tissue two of which are well developed and median in position and are chiefly yellow elastic tissue; the two glands are separated by this double septum which attaches to the medial flat surface of each gland. The lateral sheets (containing less elastic tissue), arise from the subpelvic tendon posterior to the udder; on reaching the abdominal floor they diverge and pass laterally to the external inguinal ring. They extend downward over the udder and divide into superficial and deep layers: the superficial layer attaches to the skin where it reflects off the udder to the medial face of the thigh, and the deep layer is thicker and attaches to the convex lateral surface of the udder by numerous lamellae which pass into the gland. It is in relation posteriorly to the large supramammary lymph-glands and a quantity of fat.

Bitting (*1*) was one of the first in this country to publish results of anatomical studies of the suspensory apparatus of the cow's udder. His description was general and included nothing of importance that is not covered by that of Sisson (*7*), except that he emphasized the importance of the strength of the abdominal wall as a factor in determining the shape and apparent size of the udder. He states (*1, p. 39*):

> In a cow with loose abdominal walls, dropping directly down from the pubis, thus forcing the udder downward and backward, the organ will appear to be much larger than in one in which the walls are stronger. This sometimes accounts for the apparently sudden development of a good udder after the second or third calf. The muscles of the abdomen become more relaxed and the udder becomes more pendulous.

An interesting and valuable contribution to the subject was made by Emmerson[4] who dissected several cow udders and described and illustrated many of the supporting structures. Emmerson elaborated considerably with regard to the lamellae (plates) which are given off by the deep faces of the lateral sheets, and penetrate the glandular tissue in a medioventral (inward and downward) direction to become incorporated in the insterstitial framework of

[4] EMMERSON, M. A. STUDIES OF THE MACROSCOPIC ANATOMY OF THE BOVINE UDDER AND TEAT. 1928. [Unpublished thesis. Copy on file in library of Iowa State Col. of Agr. and Mech. Arts, Ames.]

the udder. He also pointed out that the lateral suspensory ligamentous sheets continue to the ventral (lower) border of the gland at which point the lamellae anastomose and become continuous with those of the sheets of elastic tissue which make up the median septum, thus forming a sling or cradlelike structure in which the udder is held. Unfortunately the results of Emmerson's work are not available in published form. However, his work has been quoted rather freely by Turner[5] and by Espe (*3, pp. 9–10*).

There is no question as to the accuracy of Sisson's brief description of the udder's suspensory structures, or of Emmerson's elaboration concerning them. To the anatomist they are, without doubt, understandable and adequate. However, an amplified description expressed in simpler terminology and liberally illustrated should enable the research worker, the cattle judge, the dairy farmer, and all others interested in dairy cattle problems, to visualize and understand more clearly the nature of mammary-gland suspension in the cow.

In evaluating the udder capacity of living cows it would be desirable to be able to calculate the volume of the udder. To do this it is necessary to have a knowedge of the shape of the dorsal (upper) surface of the udder, and of the curvature and degree of slope of that part of the abdominal wall to which the fore udder is attached. It has been pointed out by the authors (see *9, p. 9*) that the rear and front quarters of the udder generally produce in the ratio of 3 to 2 (58.2 percent from the two rear quarters and 41.8 percent from the two front quarters), and that a similar ratio existed between the depth of the rear and front quarters of the excised udders studied (10.29 inches for the rear and 6.38 inches for the front). It is well known, of course, that the abdominal wall is lower at the anterior attachment of the udder than at more posterior points and that it curves upward toward the rear. But the shape of the curve of the abdominal wall from front to rear, or from side to side, has not been readily or accurately measured in the living cow. Neither has the outline of the dorsal surface of the udder been accurately ascertained.

PLAN OF STUDY

In order to obtain additional information that might throw light on the problems of the broken-down or pendulous udder in heavy-producing cows, and also to obtain data that might make it possible to calculate the volume of udder of the living cow, a plan was outlined for studying in detail the structures suspending the udder of a cow that was known to be a good producer. Because of the desirability of obtaining photographs of dissections of these structures in their normal position, the plan called for the work being done with the animal in a standing position. This was accomplished by following the methods that are later described.

HISTORY AND CHARACTERISTICS OF COW USED

Holstein-Friesian cow No. 1216 was selected for this study. She was 5 years 10 months of age and had been in milk for 7 months of the fourth lactation period when slaughtered. Her live weight, 4 months before slaughter, was 1,320 pounds. Her production record at 3 years 2 months of age was 14,734 pounds of milk and 540 pounds

[5] TURNER, CHAS. W. THE COMPARATIVE ANATOMY OF THE MAMMARY GLANDS WITH SPECIAL REFERENCE TO THE UDDER OF CATTLE. 378 pp., illus. Columbia, Mo. 1939. [Mimeographed.] See pp. 31–37.

of butterfat (equivalent to 17,533 pounds of milk and 643 pounds of butterfat at maturity).

The mammary-gland development of cow No. 1216 was slightly retarded until she was 2 months of age. From 3 to 5 months of age it was normal for the breed, and from 6 to 18 months it was definitely superior to the breed average. Up to 4 months of age there was a tendency for the attachments of the gland tissue to the body to be inferior. Subsequently, up to 18 months, the attachments were superior to the average. However, the attachment of the udder of this animal, both as a heifer and as a lactating cow, was poorer at the rear than at the front at nearly every examination. This was particularly noteworthy at the last examination, 3 days before slaughter, when she was given grades of 5 and 3+ respectively for front and rear attachments of gland tissue, when graded on a 9-point basis, in which 9 is excellent, 5 average, and 1 extremely poor. The gland tissue hung low in the rear quarters before slaughter and the separation between right and left halves was marked. During lactating life the udder was of fair shape and medium or above in size. The weight of the udder was not obtainable because of the method employed in slaughtering the cow and in preparing her for anatomical study. The

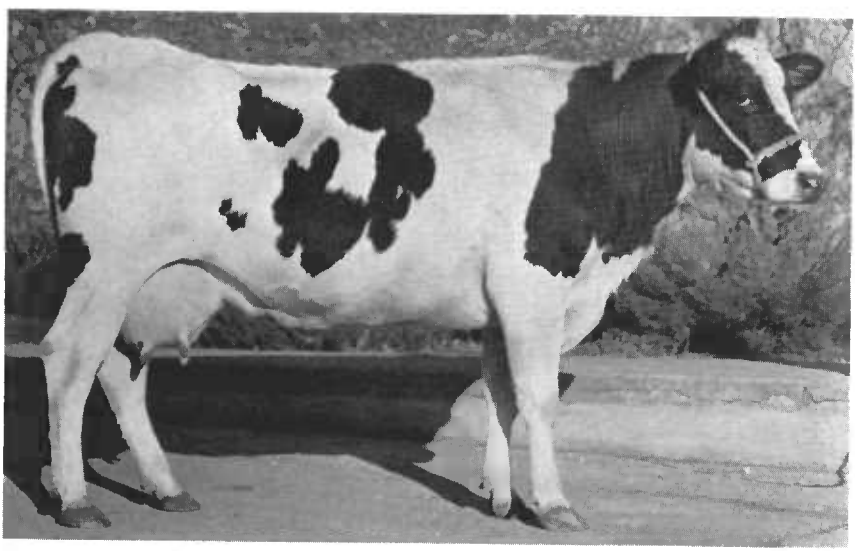

FIGURE 1.—Cow No. 1216, as she appeared about 1 month before she was killed.

udder was of medium quality and not excessively fibrous or meaty. It was somewhat inclined to be pendulous although this condition was not extreme.

Strip-cup examinations of the milk showed that this cow had had numerous flare-ups of mastitis of varying severity but of short duration. Mastitis was noted in all four lactation periods except the second. During both the first and third lactation periods all the quarters of the udder were affected at one time or another. Swelling and edema were noted prior to first calving, but neither was extreme. All of the edema had disappeared 15 days after calving and nearly all of the swelling was gone at the end of the first month. It is considered

improbable that either the mastitis or the swelling was of sufficient severity or duration to affect the suspensory structures or the attachments of the udder.

PROCEDURE FOLLOWED

The method generally employed in preparing large animals for dissection was used in this study. On the morning of January 25, 1939, the cow was rendered insensible by the injection of chloral hydrate and the subsequent administration of chloroform. She was then bled from an incision in the right carotid artery until heart action ceased, after which some residual blood was drawn by vacuum. The carotid artery and other severed blood vessels were tied off, and a glass tube, connected by a rubber hose to a tank located at an elevation some 12 or 14 feet above the cow, was inserted in the jugular vein and tied securely in position. By this means the filling of the circulatory system of the cow was commenced. A formalin solution of approximately 10-percent strength was used to preserve and harden the tissues. Meanwhile a heavy hook was inserted beneath the sacrum, and two smaller ones were inserted on opposite sides of the skull somewhat below and slightly posterior to the eyes (beneath the cheek bones or zygomatic processes of the malar bones). By means of ropes attached to these hooks the cow was hoisted into a standing position. An additional support in the form of a timber placed crosswise under the floor of the chest aided in holding the midportion of the cow at the proper height. A stoneboat was placed under the cow, the feet and legs of the cow were pulled into positions as nearly normal as possible, and each hoof was nailed to the stoneboat.

With the cow in this position, which was essentially normal except for the outstretched head, the filling of the circulatory system was continued. Within the first 3 hours about 30 gallons of formalin flowed into the jugular vein, and an additional 10 gallons was nearly exhausted some 3 hours later. During the course of the filling the udder became distended and many of the subcutaneous veins on the legs and under part of the body stood out prominently. Residual milk in the udder commenced to flow from the teats, and teat plugs were inserted. Incisions made for the supporting hooks were packed and sewed together to prevent escape of the formalin, and very little was lost. Some formalin was poured into the nostril to prevent or minimize fermentation in the rumen. Measurements of the circumference of the paunch on January 26 and 27 were 248 cm. and 247 cm., respectively. This lack of increase indicated that excessive fermentation had not occurred.

On January 27 a photograph was made showing the embalmed cow with all supports in place. The supporting apparatus was removed and the cow was again photographed. There was no significant change in the position of the cow, which showed that the tissues were adequately preserved and hardened to provide ample rigidity. The supporting equipment was replaced, however, to keep the embalmed body in an unchanged position until dissection was made. Figure 1 shows the appearance of the living cow about 1 month before she was killed. Figure 2, *A*, shows the embalmed, hardened cadaver standing, with the supporting mechanism and injection tube in position; and figure 2, *B*, shows the cadaver in the same position unsupported.

Mention has been made of the comparatively poor rear attachment of the udder which occurred in this animal as a calf and during lac-

tating life, and which was particularly noteworthy at an examination about a month before she was slaughtered. Figure 3, *A*, shows a rear view of the udder of the living cow, and figure 3, *B*, shows its appearance after she had been embalmed and hardened in situ.

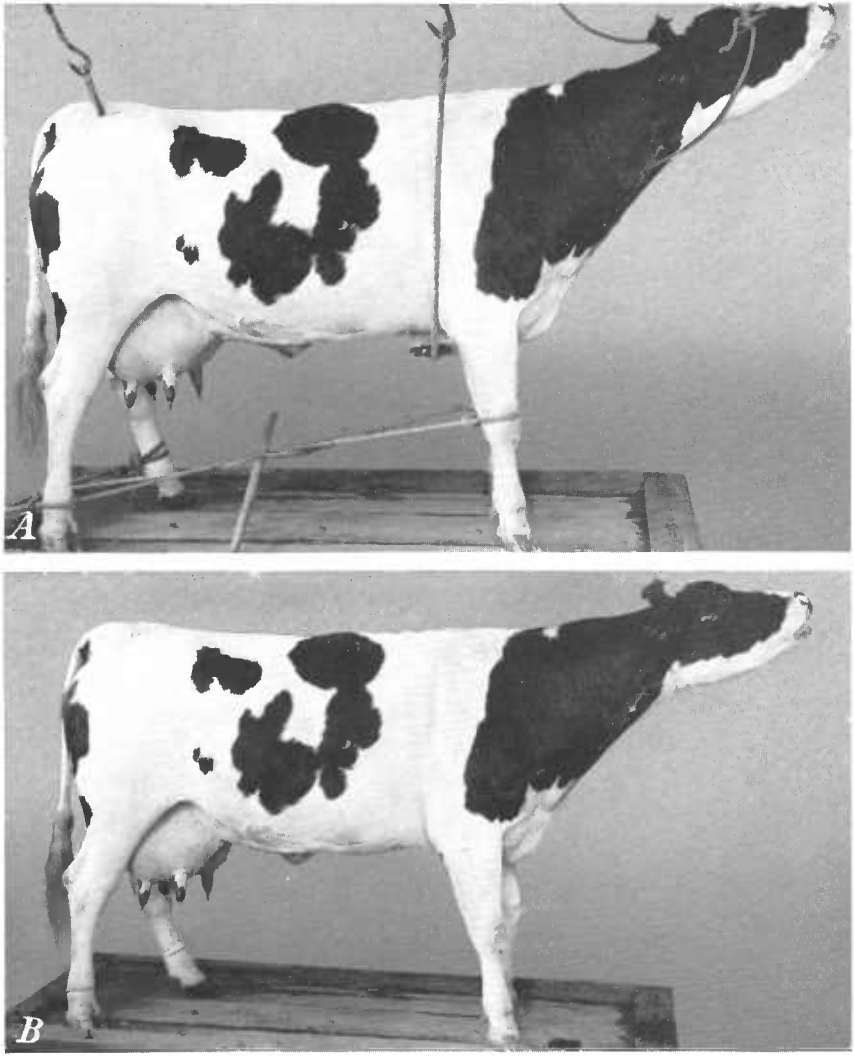

FIGURE 2.—The embalmed cadaver: *A*, With supporting equipment and injecting tube in position; *B*, with supporting equipment and tube removed.

Dissection was commenced on January 30. Photographs were taken as the work progressed and as one after another of the tissues by which the udder was suspended were uncovered. The dissecting and photographing work was carried on with the embalmed cow standing as shown in figure 2, *A*, with the hooks attached and the hoisting apparatus taut to prevent a change of position.

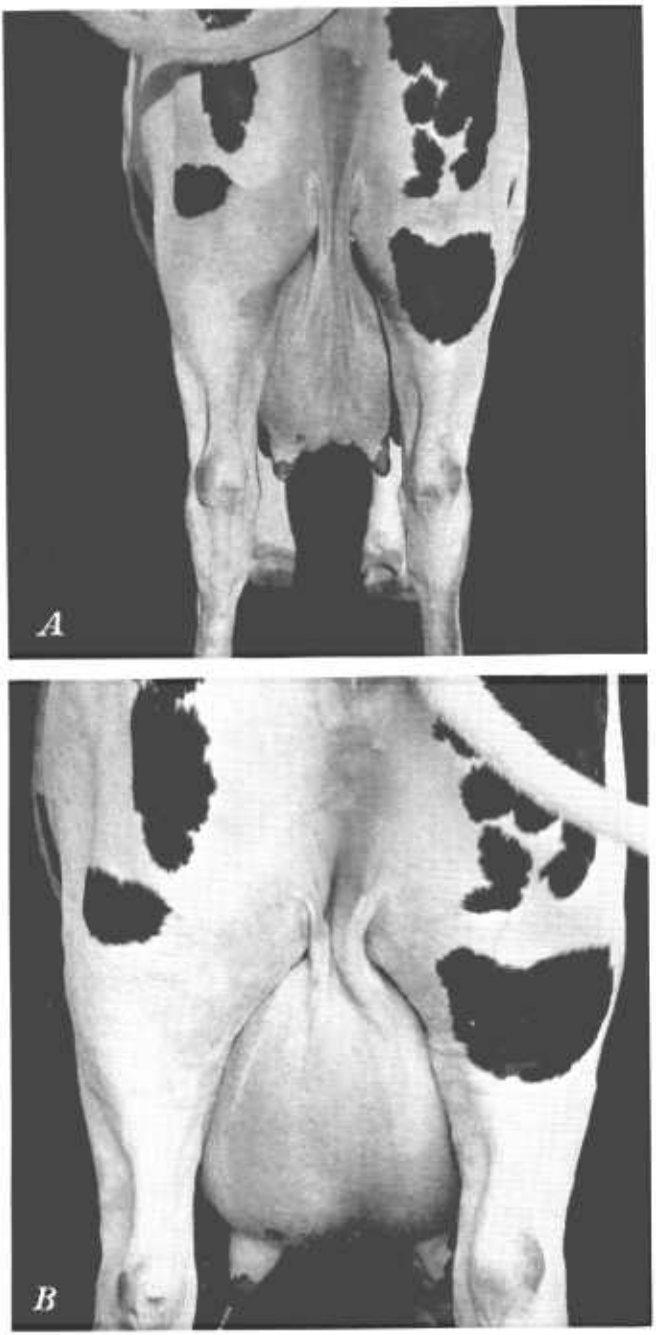

FIGURE 3.—*A*, Rear view of the udder before the death of the cow; *B*, its appearance after being embalmed.

PRESENTATION AND DISCUSSION OF RESULTS

At this point it may be helpful to list and number in the order found the principal parts of the suspensory apparatus of the udder, in order that they may be identified more easily by referring to the tissue number in the discussion of the step-by-step dissections by which they were brought to light. The principal parts of the suspensory apparatus are as follows:

Tissue No. 1.—The skin, which serves in a minor capacity to suspend and stabilize the udder.

Tissue No. 2.—The fine areolar, subcutaneous tissue (superficial fascia), which serves as an attachment between the skin and the underlying tissues.

Tissue No. 3.—The cordlike (coarse areolar) tissue, which forms a loose bond between the dorsal (upper) surface of the front quarters of the udder and the abdominal wall.

Tissue No. 4.—The pair of superficial layers of the lateral sheets of partly elastic tissue (lateral suspensory ligaments), which arise from the subpelvic tendon, extend downward and forward over the udder, and reflect off the udder to the medial (inner) face of the thigh.

Tissue No. 5.—The pair of deep, somewhat thicker layers of the lateral sheets, which have the same origin, extend downward over the udder and virtually envelop it, but which, unlike the superficial layers, attach to the convex lateral surfaces of the udder by numerous lamellae (plates) which pass into the gland and become continuous with the interstitial framework of the udder.

Tissue No. 6.—The subpelvic tendon. The tendon itself, strictly speaking, is not a part of the suspensory apparatus of the udder. Nevertheless it plays an important role as it gives rise to both the superficial and deep layers of lateral sheets described above.

Tissue No. 7.—The two adjacent sheets of heavy yellow elastic tissue, median in position, which arise from the abdominal wall, and attach to the medial flat surfaces of the two glands to form a double septum between them (median suspensory ligament).

A wide divergence of opinion exists with regard to the relative importance of these different parts of the suspensory apparatus. Emmerson [6] indicated that the median septum (tissue No. 7) is considered by most authors as the most important, but that his own observations led him to conclude that the less elastic lateral suspensory sheets (tissues No. 4 and No. 5) are the chief means of support and that the median septum merely holds the udder in close proximity to the posterior (rear) abdominal wall. In this connection he explained that the greater elasticity of the sheets comprising the median septum permits a lowering of the udder and an outward protrusion of the teats when the udder is distended with milk. He attached little importance to the fascia or areolar tissue (tissues No. 2 and No. 3) and indicated that the chief functions of the skin are to assist in the support of the fore part of the udder and to prevent undue pendulum movement.

An incision was made through the skin and subcutaneous tissue along the right flank and forward on the abdominal wall to a point somewhat anterior to the front attachment of the udder. In this manner an area of skin was dropped down exposing about half of the lateral surface of the udder and some of the abdominal wall. This showed a layer of fine areolar tissue (tissue No. 2) by means of which the udder is loosely attached to the skin. It is by means of such tissue that the skin assists in supporting and stabilizing the udder. Figure 4, *A*, shows the location and the appearance of the fine areolar tissue along the line *a*—*a*, where the skin is partly separated

[6] See reference cited in footnote 4.

from the underlying tissues. Areolar tissue of this type supposedly provides also the chief means of attachment between the hide in other parts of the body and the underlying structures. It is obvious from the well-known flexibility of the skin that this does not give a rigid attachment but permits considerable laxity and motility.

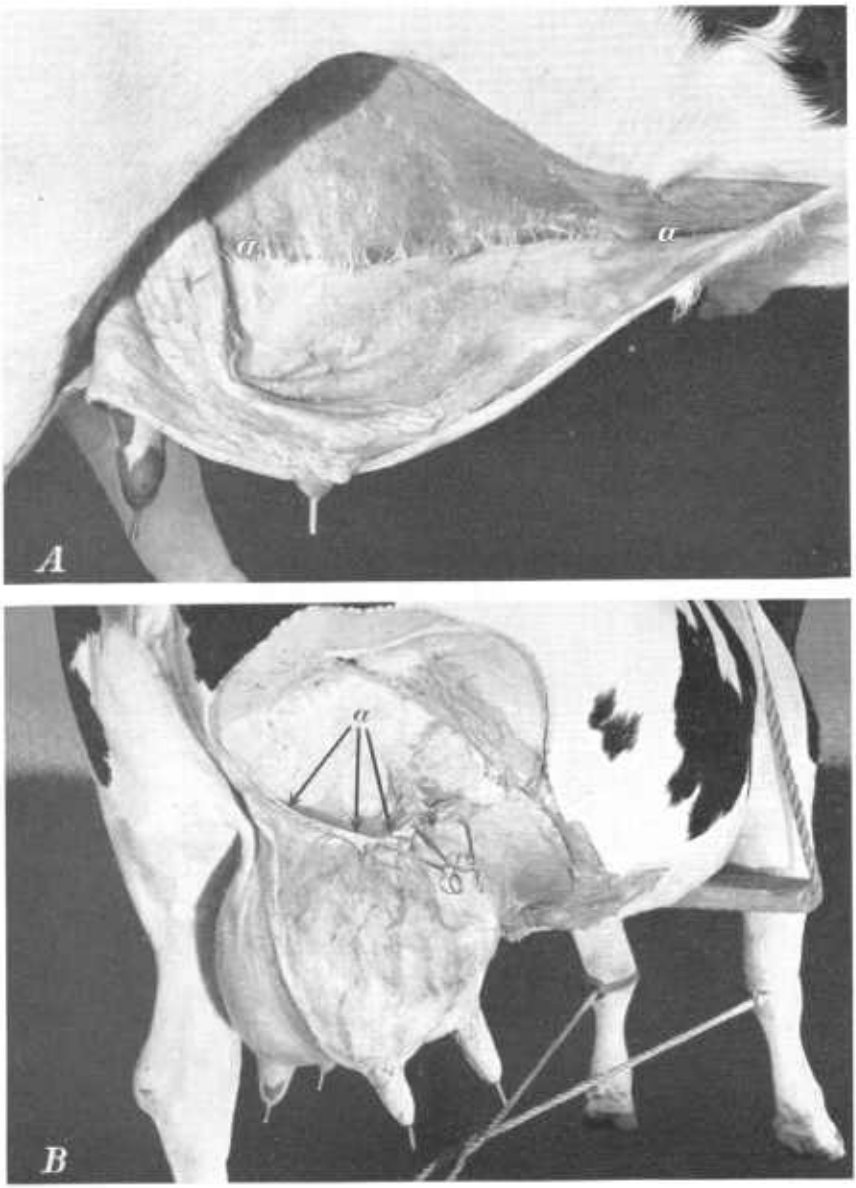

FIGURE 4.—*A*, Location and appearance of the subcutaneous fine areolar tissue (tissue No. 2) where the skin is folded down along the line *a*—*a*; *B*, portion of a partly enveloping sheet of fibrous tissue (tissue No. 4) which originally had been attached to the muscular tissues of the thigh. The severed edge is shown along the line indicated by *a*. Right hind leg removed.

The right hind leg was next removed at a point just below the hip joint, together with an area of skin extending from the tips of the teats upward to the level of the hip joint (thurl) and forward to a point somewhat anterior to the front attachment of the udder. This revealed more fine areolar tissue (tissue No. 2) and a sheet of fibrous partly elastic tissue which was still attached to the abdominal wall and which originally had been attached to the muscular tissues of the thigh. A portion of this sheet of tissue (tissue No. 4) was severed along the posterior dorsal (rear upper) surface of the udder, and is shown stretched out laterally by means of forceps attached to a cord

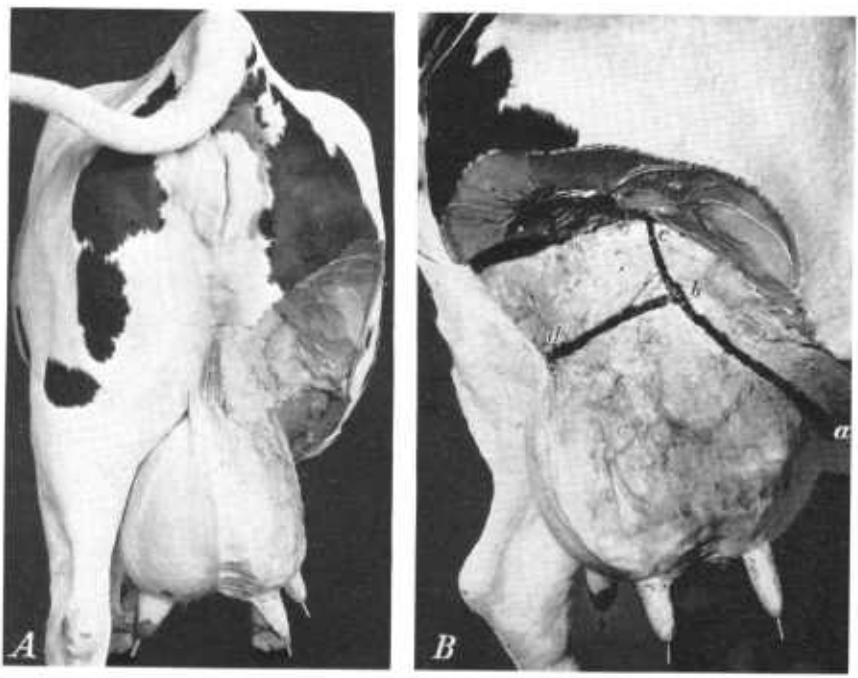

FIGURE 5.—*A*, Posterior view of the udder showing how it narrows dorsally to accommodate the thigh; *B*, lateral view with the upper boundary of the gland tissue outlined with a stain. Line *a*—*b*—*c* shows the line of the abdominal wall; *b*—*d*, the upper boundary of the udder. Note how the upper boundary of the udder follows the contour of the abdominal wall to a point approximately below the brim of the pelvis and then inclines downward toward the rear.

(fig. 4, *B*). It will be noted that this layer of tissue is fairly close to the median line at the rear and that it flares out toward the front. It partly envelopes the udder and serves as an important unit of its suspensory apparatus. The line on which the separation was made is indicated by *a*.

A posterior (rear) view of the udder at the same stage of dissection (fig. 5, *A*) shows the contour of the udder and indicates how markedly it narrows toward its dorsal (upper) extremity, especially at the rear, to provide ample space for the thigh. A lateral (side) view, also at the same stage of dissection, shows the approximate upper boundary of the gland tissue which has been outlined with a staining material (fig. 5, *B*). It will be noted that the upper boundary follows the

contour of the abdominal wall to a point almost directly below the brim of the pelvis, which is very close to a vertical plane passing through the two hip joints, after which, in this case at least, it inclines downward toward the rear. It is likely that in cows having a firm rear attachment of the udder, the upper surface of the gland tissue posterior to the brim of the pelvis may continue in a more nearly horizontal plane.

Figure 6, *A*, shows a posterior view of the udder after the removal of both hind legs. The posterior median support consisting of tissues

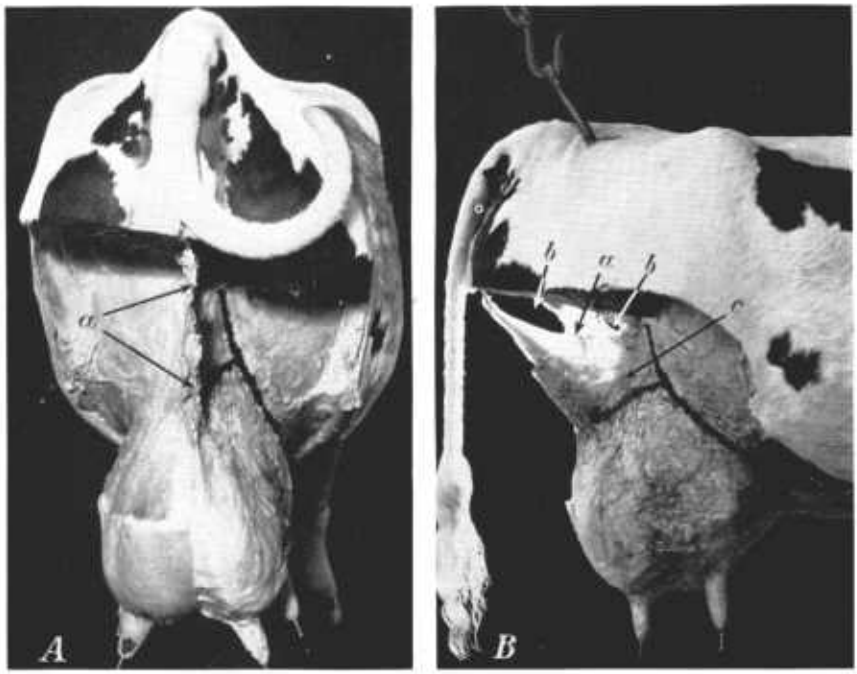

FIGURE 6.—*A*, Posterior view of the udder showing posterior median support at *a*, and indicating the contour of the udder, the angle of abdominal inclination, and the relatively small portion of the abdominal wall covered by the udder; *B*, lateral view showing the translucent subpelvic tendon (*a*) (tissue No. 6) which connects the lateral sheets of connective tissue (tissues No. 4 and No. 5) that are attached to the udder at *c* with the ventral surface of the pelvis. Open spaces in the subpelvic tendon are shown at *b*.

attached to the subpelvic tendon (tissue No. 6) is indicated by *a*. This view also gives a good idea of the contour of the udder itself, the angle of abdominal inclination, and the relatively small portion of the abdominal wall covered by the udder.

A better idea of the nature of the posterior median support of the udder is obtainable from the illustration in figure 6, *B*. This side view shows a closer dissection of the strong subpelvic tendon (tissue No. 6), which connects the lateral sheets of connective tissue that are directly attached to the udder (tissues No. 4 and No. 5) with the ventral (lower) surface of the pelvis (symphysis pelvis). This view, which was illuminated from the opposite side when photographed, shows how the subpelvic tendon becomes increasingly translucent (semi-

transparent) as it changes in structure from the mixture of fibrous and tendinous tissues at the udder, to a thin tendinous sheet where it attaches to the pelvic bone. The subpelvic tendon is not continuous but consists of a number of separated points of attachment along the ventral (lower) ridge of the pelvis. In figure 6, *B*, *a* indicates the translucent subpelvic tendon (tissue No. 6), *b* and *b* indicate the interstices (open spaces) in the tendon, and *c* shows the point where the lateral sheets of the udder's suspensory apparatus (tissues No. 4 and No. 5) arise from the subpelvic tendon.

Despite the inferior rear attachment of this udder its position was not so far forward as to appear unusual in the living cow. However, when the dissection had progressed to the stage illustrated in figure 6, *B*, the udder seemed to be located surprisingly far to the front although actually its position was essentially unchanged.

For purposes of record a number of measurements were made to establish more definitely the size of the udder, the extent of its attachment to the abdominal wall, and its position with reference to other points in the pelvic region. The following are some of the measurements obtained:

Measurement	*Centimeters (Inches)*
(1) Distance from a perpendicular through the posterior point of the pinbone (ischium) to a vertical, transverse plane through the—	
(a) Posterior (rear) extremity of udder (right side)	22.0 (8.66)
(b) Most posterior (rear) extremity of abdominal wall (its junction with the brim of the pelvis)	38.5 (15.16)
(c) Anterior (front) extremity of udder (right side)	61.0 (24.02)
(d) Calculated length of udder	39.0 (15.35)
(2) Greatest width of udder at a vertical plane through rear teats	29.5 (11.61)
(3) Greatest width of udder at a vertical plane through front teats	32.75 (12.89)
(4) Maximum width of attachment to the abdominal wall	24.75 (9.74)
(5) Width of abdominal attachment at a vertical plane through front teats	20.75 (8.17)
(6) Width of abdominal attachment at a vertical plane through rear teats. (See dorsal boundary line in fig. 7, *B*)	8.50 (3.35)

Figure 7, *A*, shows a view in which the deep lateral layer of the suspensory apparatus (tissue No. 5) has been partly separated from the abdominal wall to show a layer of cordlike tissue lying between the dorsal (upper) surface of the udder and the abdominal wall. This tissue, which apparently provides the means by which most of the dorsal surface of the udder is attached to the abdominal wall, is areolar in type, very coarse, and loosely bound together. Presumably, in the event of excessive udder weight, or as a result of an inherited weakness or other causes, this tissue might give way and permit a separation between the udder and the abdominal wall with a characteristic breaking away of the front attachment of the udder. Emmerson's comment regarding the relative lack of importance of these tissues is worthy of note. Figure 7, *A*, *a* shows the loose cordlike tissue (tissue No. 3) and *b* the partly severed deep lateral layer of the enveloping suspensory tissue (tissue No. 5).

The completely severed deep lateral layer of the suspensory tissues which attaches to the convex lateral surface of the udder and virtually envelops it (tissue No. 5) is shown in figure 7, *B*. A portion of this layer below the horizontal incision was dissected away from the udder and folded downward along the line *b*—*b* (fig. 7, *B*) in such

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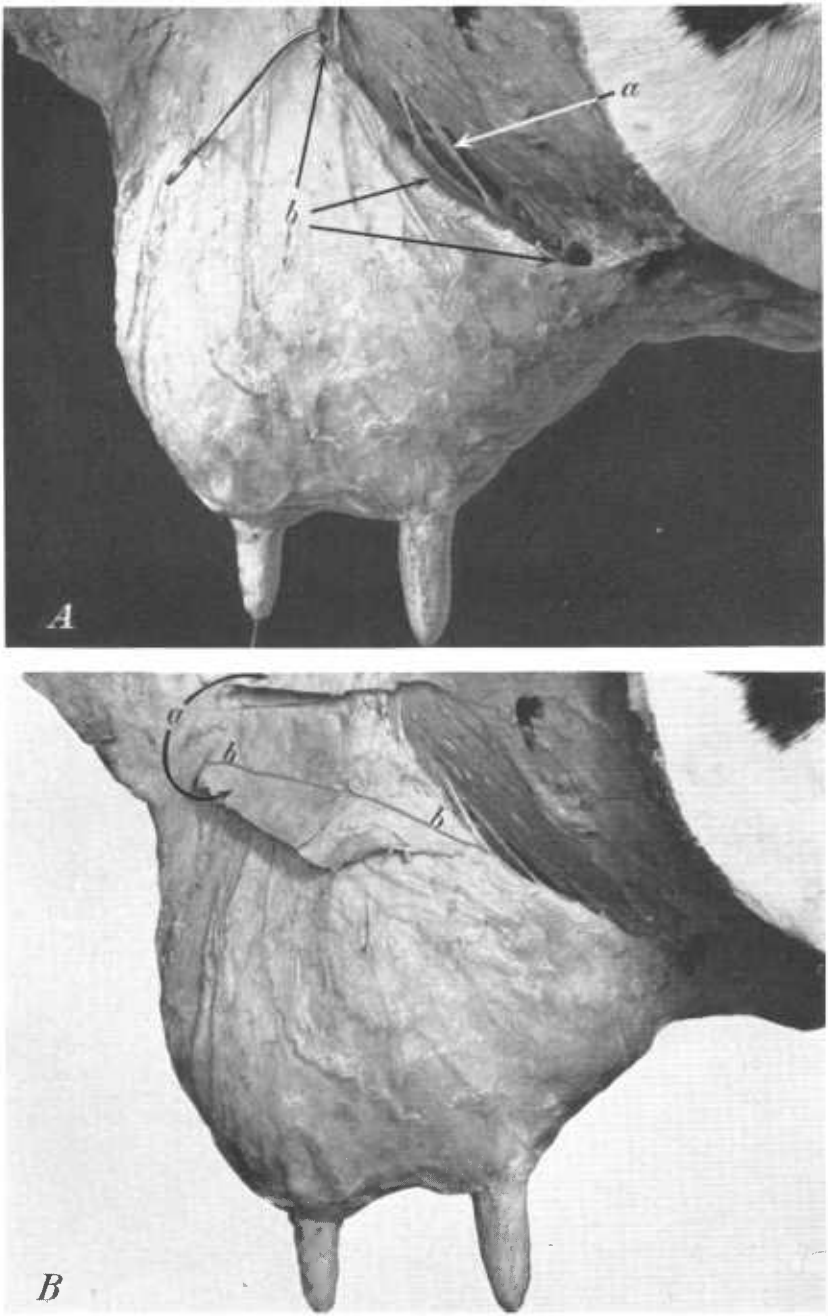


FIGURE 7.—*A*, The deep lateral layer of enveloping suspensory tissue (tissue No. 5) partly separated from the abdominal wall at *b* to show cordlike tissue (*a*) (tissue No. 3) which serves to hold the udder in contact with the abdominal wall; *B*, the deep lateral layer (tissue No. 5) severed at *a* and folded back along the line *b*—*b*.

a manner as to reveal the two edges, indicated by *a*, which were formed by the incision. As shown in the illustration, this layer consisted of a clearly defined sheet of tough tissue which became continuous, ventrally (below), with the udder. The cordlike tissue along the abdominal wall (tissue No. 3) is shown here also, but less distinctly than in figure 7, *A*. It is conceivable that, in cases where the loose, cordlike tissue gives way, the enveloping layer of tissue and the median elastic support (tissue No. 7) may stretch sufficiently to permit a lowering of the udder—especially in front—which would thereby become pendulous.

The deep lateral layer (tissue No. 5) which previously had been severed (fig. 7, *B*) was separated from the udder to a lower level and folded downward along the line *a–a*, shown in figure 8, *A*. Figure 8, *A*, also shows how the dissection on the right side was carried deeper with the removal of a considerable quantity of fat and connective tissue, bringing to light the small areas of parenchymatous (secretory) tissue shown at *b*; the branch of one of the two yellow elastic supporting sheets of tissue (tissue No. 7) shown at *c*, which form the median septum of the udder; one of the large arteries where it enters the udder as shown at *d*; and a large vein on the dorsal (upper) surface of the udder at the point where it emerges from the udder as shown at *e*. The subpelvic tendon (tissue No. 6) is still attached (fig. 8, *A*, *f*).

Figure 8, *B*, shows the udder from the left at essentially the same stage of dissection as in figure 8, *A*, except that more of the deep, lateral enveloping layer of suspensory tissue (tissue No. 5) has been removed from the anterior (front) part of the udder, whereas at the rear of the udder a section of it (fig. 8, *B*, *a*) is still intact and attached both to the mammary gland and to the subpelvic tendon. A large vein extending along the abdominal wall at the upper surface of the udder is clearly visible (fig. 8, *B*, *b*).

It seems appropriate at this point to give attention to a matter that was not satisfactorily brought out in the gross dissection of the udder used in this study. Sisson (*7*), Emmerson,[7] Turner,[8] and Espe (*3, pp. 9–10*) mentioned the lamellae (plates) that are given off by the deep faces of the deep lateral sheets (tissue No. 5) which penetrate the udder and join with its intraglandular interstitial framework. A histological study of sections including the lateral sheets and the glandular tissues immediately beneath shows the manner in which the lamellae branch off and extend downward and inward to become continuous with the intraglandular tissues (pl. 1, *A*). This study brought out the fact that the sheets comprising the median septum (tissue No. 7) also give rise to lamellae which penetrate the glandular tissue in a similar manner (pl. 1, *B*).[9]

It is more difficult to determine to what extent the lateral and median sheets fuse at the ventral (lower) border of the gland to form a sling or cradlelike structure for its support. This is because of the laminated nature of both the lateral and median sheets and the fact that numerous branches are given off. A section through an udder that was included in routine studies of the Bureau of Dairy Industry shows a band of tissue that appears to extend continuously around

[7] See reference cited in footnote 4.
[8] See reference cited in footnote 5.
[9] The illustrations shown in plate 1, *A* and *B*, were made available through the cooperation of John D. Hunt, Division of Nutrition and Physiology, Bureau of Dairy Industry.

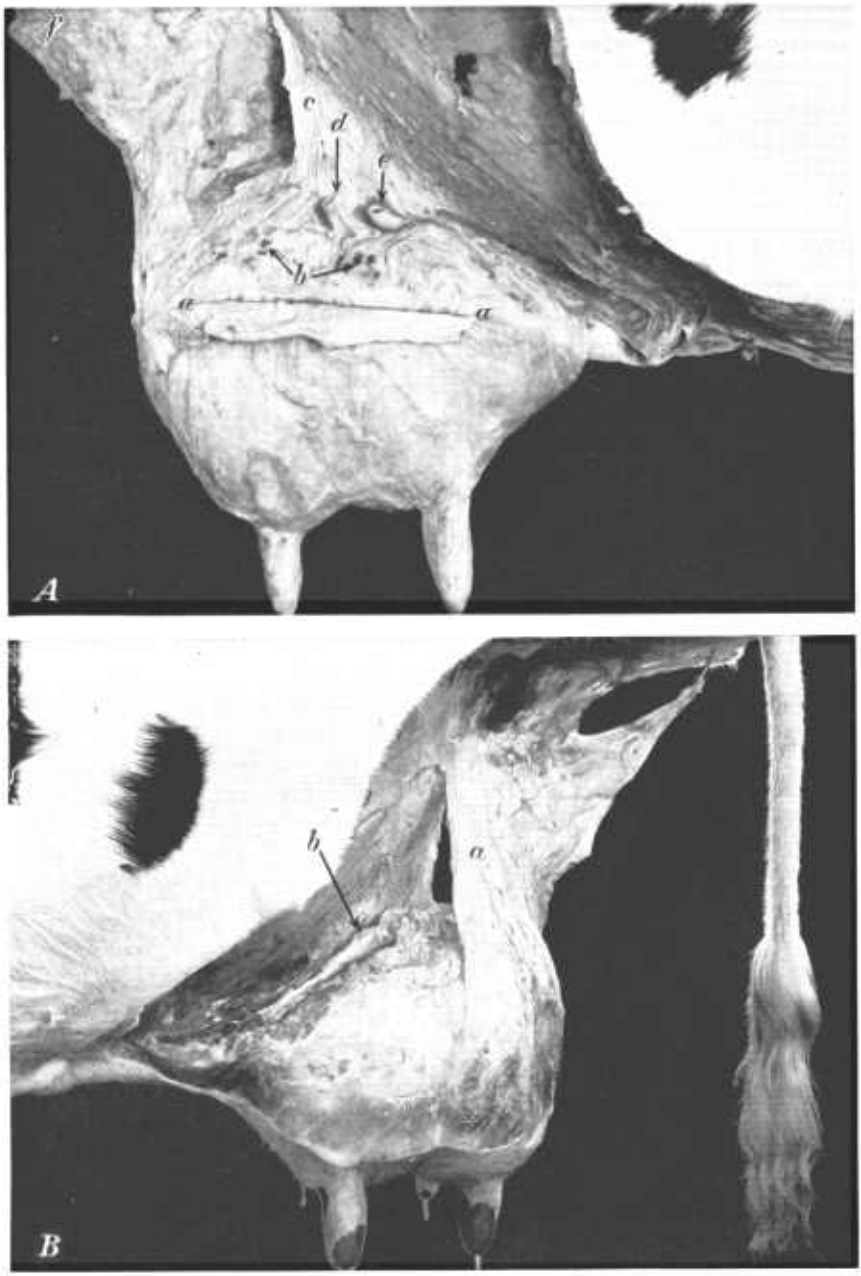
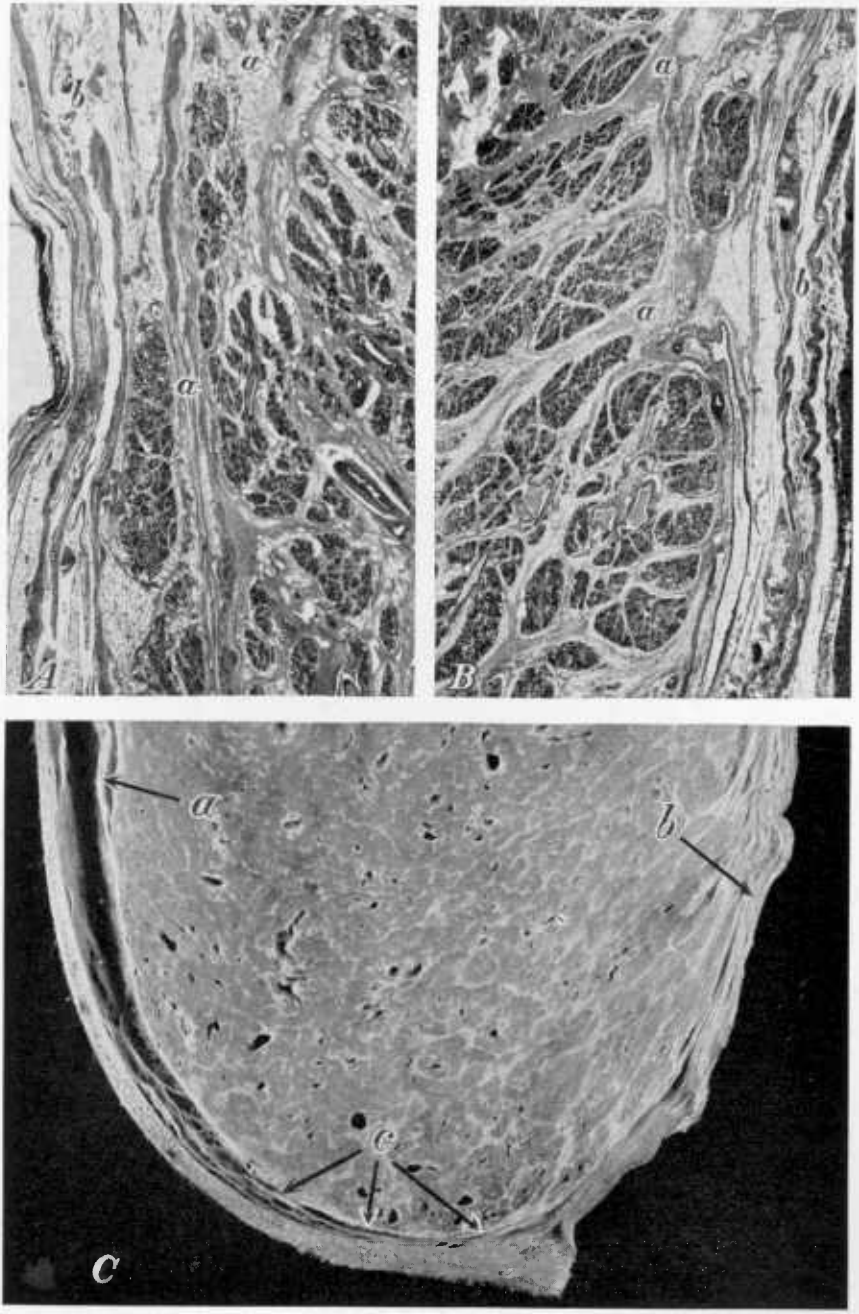


FIGURE 8.—*A*, Deeper dissection in which the deep lateral layer (tissue No. 5) is folded downward to a lower level revealing small areas of mammary-gland tissue (*b*), a portion of one of the median yellow elastic supporting sheets (*c*) (tissue No. 7), a large artery (*d*), and a large vein (*e*); the subpelvic tendon (*f*) (tissue No. 6) is still in position. *B*, Left side of udder with anterior part of deep lateral layer removed but with posterior part (*a*) still attached to udder and subpelvic tendon. A large vein is shown at *b*.



A, Lamellae (*a*–*a*) branching off from the deep lateral sheet (*b*) (tissue No. 5), and extending inward and downward to become continuous with the intraglandular tissues of the udder; *B*, similar lamellae (*a*–*a*) arising from one of the sheets (*b*) (tissue No. 7) which form the median septum; *C*, a band of tissue that appears to make the lateral (*a*) and median (*b*) layers (tissues No. 5 and No. 7) continuous around the ventral (lower) border of the gland (*c*).

the ventral (lower) border of the gland from the lateral to the median surface (pl. 1, *C*).

In figure 9, *A*, the udder is shown with all of the supporting tissues removed except a small area of areolar tissue and skin at the anterior (front) extremity of the mammary-gland tissue *b*, and the main portion of the deep medial, yellow elastic tissue *a* (tissue No. 7) which is attached to the abdominal wall above and continues below to form the septum between the halves of the udder. Apparently the areolar tissue and skin carried little weight. The white strip *c* between the abdominal wall and the dorsal surface of the udder is the result of light coming from the opposite side. It shows that all the supporting tissues in this area had been completely severed.

In figure 9, *B*, the udder is shown with all supporting structures removed except the main portion of the deep medial yellow elastic tissue *a* (tissue No. 7) that was pointed out in figure 9, *A*. The length (front to rear) of this layer of tissue, as shown, was 16.5 cm. (6.50 inches) where it attached to the abdominal wall, but was only 11.0 cm. (4.33 inches) at its shortest point. The great strength and the nearly perfect location of this median support are noteworthy. The weight of the udder, dissected as shown in figure 9, *B*, with the formalin it contained, was 47.0 pounds. Although the left half of the udder apparently was heavier than the right—a condition that caused the udder to list slightly to one side—its position when suspended from the short narrow sheet of median tissue as shown in figure 9, *B*, was otherwise not significantly changed from its position on the living cow. Measurements of the height of the tips of the rear and front teats were made from time to time as the dissection progressed. The heights measured at midafternoon on January 30, at the conclusion of the dissection shown in figure 6, *B*, were 37.5 cm. (14.76 inches) for the rear teats and 40.3 cm. (15.87 inches) for the front teats. Up to this time no settling or significant change in the position of the udder was apparent. After overnight suspension following the dissection shown in figure 6, *B*, the heights were 37.2 cm. (14.65 inches) and 39.7 cm. (15.63 inches), respectively, for rear and front teats. With the udder supported as shown in figure 9, *A*, the corresponding heights were 36.6 cm. (14.41 inches) and 39.5 cm. (15.55 inches) respectively, and after all of the supporting structures except the main portion of the medial yellow elastic septum had been severed (fig. 9, *B*) the heights were 36.3 cm. (14.29 inches) and 39.5 cm. (15.55 inches) for rear and front teats. These measurements indicate a total settling of only 1.2 cm. (0.47 inch) for the rear of the udder and only 0.8 cm. (0.31 inch) for the front since midafternoon of the previous day during which time all except one of the main supports of the udder had been removed. Obviously the median elastic tissue not only possessed great tensile strength, but it was so nearly perfectly located above the anteroposterior center of gravity that the udder was in almost a perfectly balanced suspension, when all other structures had been removed.

The results observed in this experiment appear to indicate that the medial septum is the principal structure by which the udder is sus-

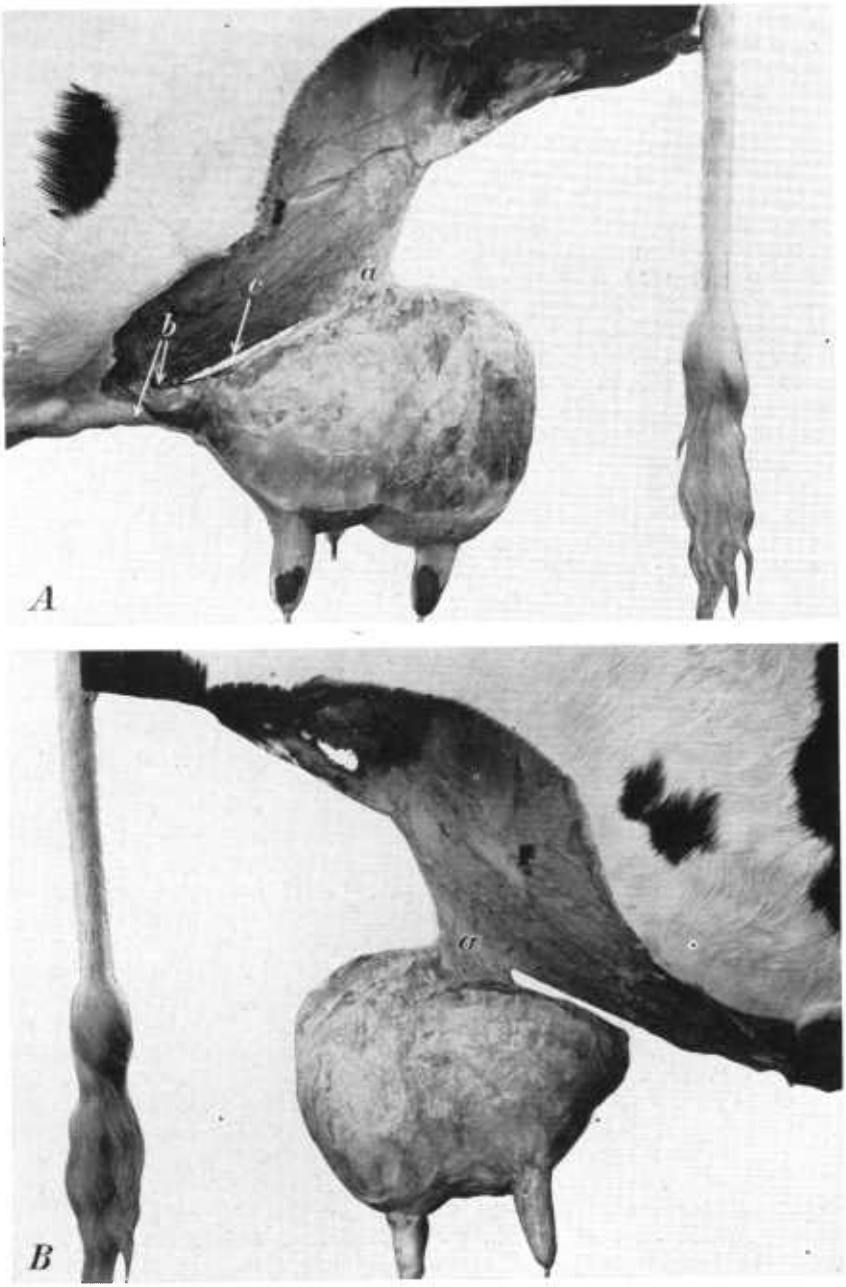


FIGURE 9.—*A*, Udder as seen from left, with all supporting structures removed except the main part of the medial yellow elastic tissue (*a*) (tissue No. 7) and a small area of skin and areolar tissue (*b*); a streak of light shows between the abdominal wall and the udder at *c*. *B*, View from the right with the medial yellow elastic tissue (*a*) remaining as the only support for the udder, note the almost perfectly balanced suspension of the udder.

pended. No other experiments were conducted to determine to what extent the other membranes could have supported the udder in position. It is of interest to note that the medial septum was attached to the abdominal wall but apparently not directly to any bony structure.

A rear and somewhat superior view of the udder at the same stage of dissection (fig. 10, *A*) indicates the narrowness of the main portion of the double sheet of medial tissue (tissue No. 7) shown in figure 9, *B*, which furnishes one of the chief supports of the udder and forms the septum that separates the two halves. The somewhat wider and heavier left half of the udder and the resulting swing of the entire organ to the right are clearly indicated.

At this point the right half of the udder was removed by means of a longitudinal incision that was carried as close as possible to the right of the median septum. Figure 10, *B*, shows the surface from which the right half of the udder was removed. It indicates the manner in which the supporting medial tissue (tissue No. 7) *a* spreads out in a fan-shaped manner to form a septum that reaches and attaches to nearly all parts of the medial flat surface of the gland. Apparently the fan-shaped distribution of this septum provides maximum support to the udder and accounts for its almost perfectly balanced suspension.

Figure 11, *A*, is a rear view that shows the shape and the appearance of the abdominal wall after the medial support of the udder was severed along the line *a*—*a*. In this view *b* shows a severed abdominal vein ("milk vein"), *c* is one of the ventral (lower) points of the symphysis pelvis to which the subpelvic tendinous support of the udder was attached, and *d* and *d* are the front legs of the cow.

Figure 11, *B*, is a lateral view of the abdominal wall at the same stage of dissection. It shows both the angle of inclination and the degree of curvature of the abdominal wall from the point at *b*, where the anterior (front) extremity of the udder had been attached, to the pubis at *c* (anterior part of pelvic floor). In this view a point of the symphysis pelvis (under median surface of pelvis) is shown at *d*, and the tendinous stump which formed the point of attachment for the median support of the udder is again indicated by *a*.

In addition to the photographs shown in figure 11 a number of measurements were taken to show the shape and position of the abdominal wall in the area where the udder had been attached. This study of the shape of the abdominal wall in relation to that of the dorsal (upper) surface of the udder was undertaken for the purpose of providing, if possible, some means of estimating the hidden boundaries of the udder and thereby of calculating udder volume in the living animal. The measurements were made with the embalmed cadaver still supported in the position shown in figure 2, *A*, with the udder and extraneous tissues dissected away as shown in figure 11. The measurements consisted of (1) horizontal distances from a perpendicular transverse plane located at the posterior extremity of the pinbone (ischium) to specified, previously located points; and (2) heights of the same points above the surface (of the stoneboat) to

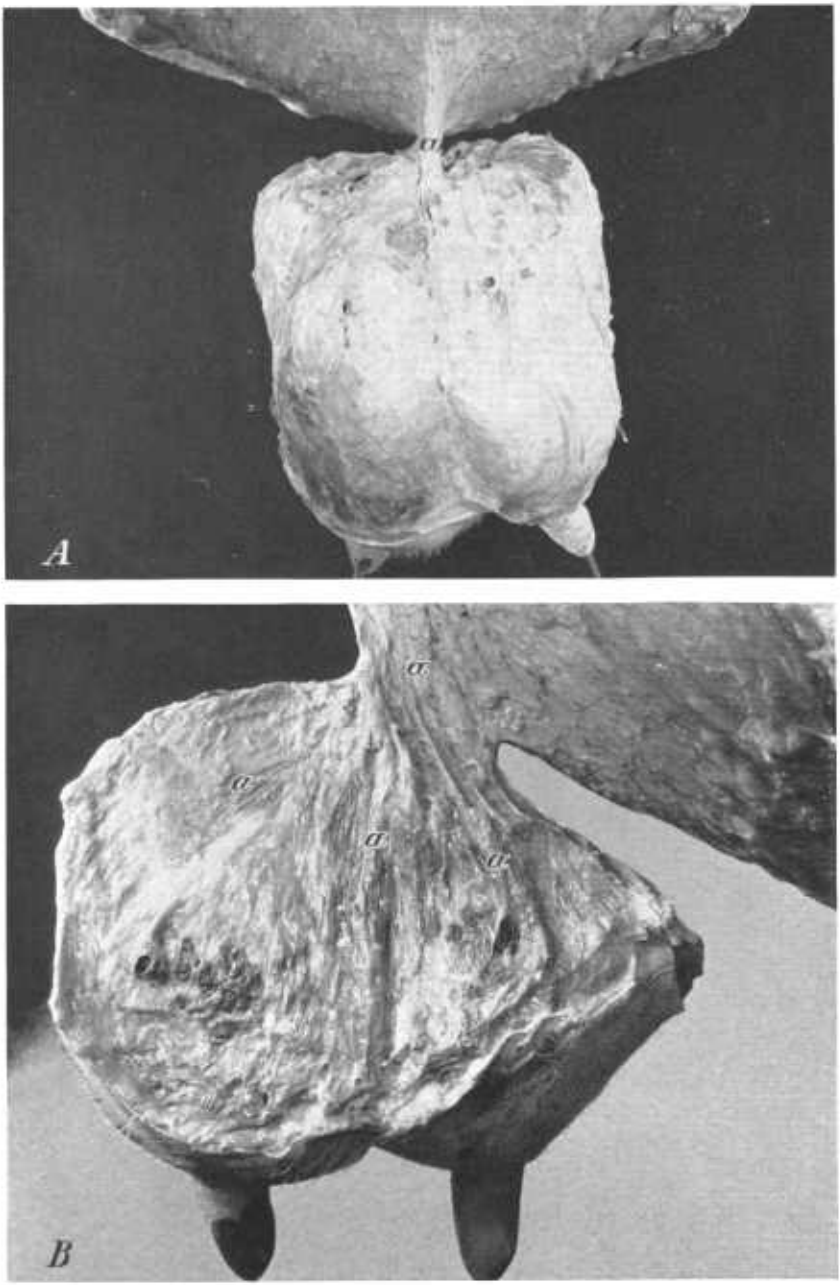


FIGURE 10.—*A*, Rear view of the udder from slightly above, showing the narrowness of the main part of the medial yellow elastic tissue (*a*) which is capable in itself of supporting the udder without material change of position; *B*, surface from which the right half of the udder has been separated to illustrate the fan-shaped attachment (*a*) of the septum to the medial surface of the udder.

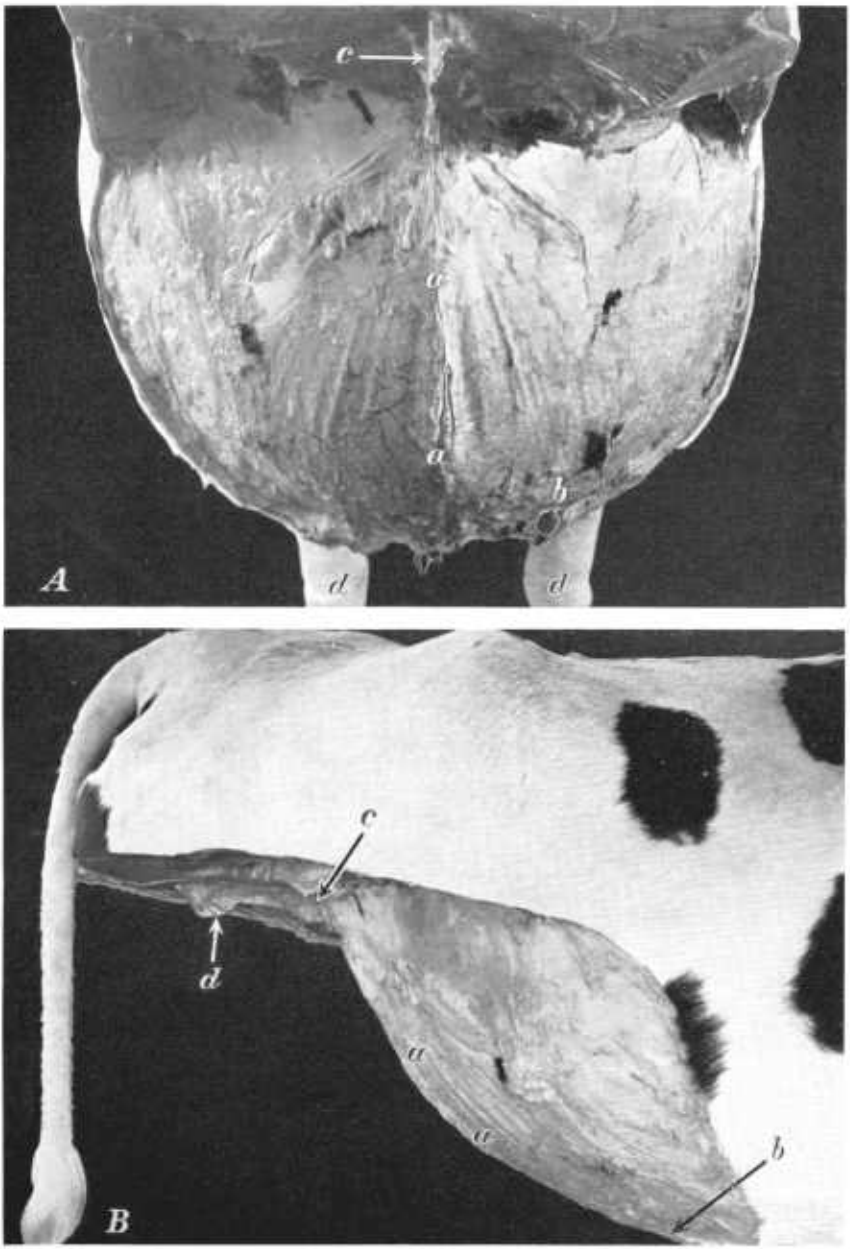


FIGURE 11.—*A*, Rear view of the abdominal wall after removal of udder: *a—a*, The line where medial septum was severed; *b*, a milk vein; *c*, one of the points at which the subpelvic tendon was attached to the pelvis; *d*, the front legs. *B*, Lateral view of the abdominal wall: *b*, The anterior point of attachment of the udder; *c*, the approximate location of the brim of the pelvis; *d*, the symphysis pelvis; and *a–a*, the tendinous stump of the medial yellow elastic supporting septum. Note that this medial septum was attached to the abdominal wall and not directly to any bony structure.

which the cow's feet were attached. The measurements obtained were as follows:

Measurement	*Centimeters*	*(Inches)*
(1) Anteroposterior length on the median line from a vertical transverse plane at the posterior extremity of the pinbone (ischium) to the intersection of the abdominal wall and a vertical transverse plane through—		
The navel	88. 50	(34. 84)
The anterior attachment of the udder	62. 00	(24. 41)
A front teat (right)	49. 50	(19. 49)
A rear teat (right)	35. 75	(14. 07)
(2) Height of the abdominal wall at the median line, above the surface to which the feet had been attached (stoneboat), in a vertical transverse plane through—		
The navel	56. 00	(22. 05)
The anterior attachment of the udder	62. 75	(24. 70)
A front teat (right)	73. 75	(29. 04)
A rear teat (right)	92. 00	(36. 22)

From these measurements the medial anteroposterior (front to rear) curvature of the abdominal wall was plotted. The plotted curve is shown in Figure 12, *A*, in which the line *o*—*x* represents the vertical transverse plane at the posterior (rear) extremity of the pinbone; *o*—*y*, the surface to which the cow's feet were attached (stoneboat); *a*, the navel; *b*, the anterior attachment of the udder; *c*, a vertical transverse plane through the front teats; and *d*, a vertical transverse plane through the rear teats. The distances from *o*—*x* and *o*—*y* to the points *a*, *b*, *c*, and *d* are shown in the graph.

By the use of special apparatus three contours were drawn (fig. 12, *B*) to show the transverse curvature of the abdominal wall at the vertical transverse planes passing through the navel (*a*), the anterior attachment of the udder (*b*), and a front teat (*c*). Plane *d* intersected the abdominal wall at a point too close to its junction with the pelvis to permit making a significant contour.

SUMMARY AND CONCLUSIONS

This study has made it possible to visualize and to illustrate the position and appearance of the principal structures by which the cow's udder is suspended. The fine areolar subcutaneous tissue by means of which the skin covering the udder is attached to the underlying tissues; the cordlike coarse areolar tissue which forms a loose connection between the upper surface of the front quarters of the udder and the abdominal wall; the superficial lateral sheets which arise from the subpelvic tendon, extend downward over the udder and attach to the thigh; the deep lateral sheets that have a similar origin but which virtually envelop the udder and attach directly to its outer surfaces by numerous plates that pass into the gland; the subpelvic tendon itself, from which the superficial and deep lateral layers arise; and the heavy yellow elastic sheets which arise from the abdominal wall, form a fan-shaped septum between the two halves of the udder, and serve as its chief median support and stabilizer, are all clearly shown in the illustrations that accompany the discussion.

Fleshy udders, udders that become edematous, and the udders of high-producing cows often become excessively large and heavy—particularly with advance in age—and overtax the structures by which they are suspended from the body. It is not difficult to imagine how, in these very large udders, any or all of the various sheets of supporting

tissues might become lax and stretch, and how the areolar tissue might pull apart in cases where any of the other tissues lose their normal tonus. It is likely also that a weakness in the suspensory

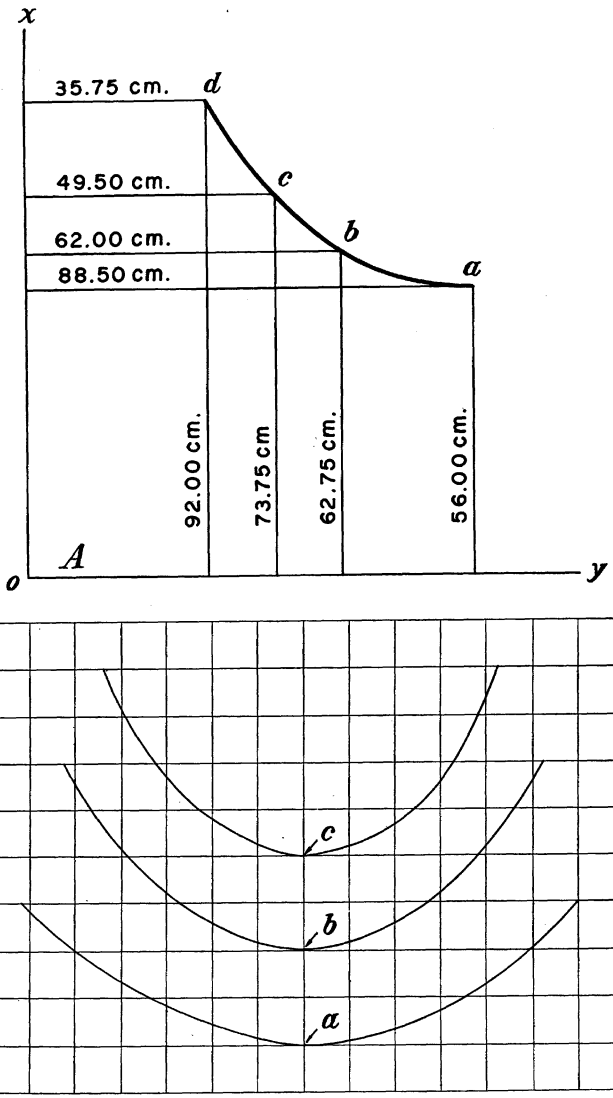


FIGURE 12.—*A*, Curve constructed from measurements to show the medial anteroposterior (front to rear) curvature of the abdominal wall from the navel (*a*) to the brim of the pelvis (*d*); measurements show distances from the floor and from the perpendicular at the rear of the pinbone (see text). *B*, The transverse curvature of the abdominal wall: *a*, At the navel; *b*, at the anterior (front) attachment of the udder; and *c*, directly above the front teats.

apparatus might occur as a result of inheritance or of a generally poor physical condition, and bring about a similar "breaking down" in udders that have not become excessively enlarged by fleshiness,

edema, or high production. The occurrence of poorly supported udders in young cows—sometimes early in first lactation—is an indication that such is the case.

The great tensile strength of the median elastic support of the udder (tissue No. 7), and its almost perfect location above its center of gravity are particularly noteworthy. In the case studied the main portion of this median support, which was less than 4½ inches long (front to rear) at one point, and had only a 6½-inch attachment to the abdominal wall, was capable in itself of holding the udder in an almost perfectly balanced suspension. Undoubtedly its fan-shaped attachment to the medial faces of each half of the udder accounted largely for the balance of the udder.

It probably is this median supporting tissue that becomes excessively relaxed in cases where the udder sags along the median line and the teats point outward laterally. It is likely also that a lack of tonus in the lateral sheets of supporting tissue (tissues No. 4 and No. 5), together with a separation of the fibers of the areolar tissues (tissues No. 2 and No. 3), may cause the udder to break down on the sides (front, rear, or both) with the result that the active support becomes very narrow and appears to be almost entirely median.

The dorsal (upper) surface of the udder does not, as has sometimes been supposed, follow a continuous curve from its anterior to its posterior attachments. It appears to follow quite closely the curve of the abdominal wall toward the rear to a point approximately under the brim (front) of the pelvis, but subsequently it carries out in a generally horizontal plane or may incline downward. In the case of the cow studied the dorsal surface of the udder posterior to the brim of the pelvis inclined rather definitely downward toward the rear. In this connection the poor rear attachment of the udder in this animal both as a calf and as a cow is again pointed out.

It is noteworthy that in the cow dissected the junction of the abdominal wall and the pubis—almost directly below the acetabulum (hip joint)—was located superiorly (above) and essentially in a vertical transverse plane passing through the rear teats. Presumably the relative location of the teats with reference to these points will vary with individual cows, depending largely on the shape and position of the udder.

The study of this cow emphasized the fact that the area of contact between the dorsal surface of the udder and the abdominal wall was very much smaller than the area of a horizontal transverse section through the udder.

Owing to the fact that the dorsal (upper) surface of the udder does not attach directly to the abdominal wall, or coincide with it in shape, posterior (to the rear) to a plane approximately at the midpoint of the udder, it is doubtful whether the curvature of the abdominal wall can be used as a reliable guide in estimating the size or volume of the udder in the living cow. The difficulty in making an accurate estimate of udder volume is complicated also by the fact that the dorsal (upper) contour of the udder is dependent to a very great extent on the quality and nature of its suspensory apparatus, which appears to vary greatly in individual animals. Moreover, such an estimate is likely to be inaccurate on account of the possibility that laxity in the abdominal muscles may alter the shape and position of the udder.

This study, by illustrating the form and nature of the apparatus by

which the udder is attached to the cow's body, should make possible a better understanding of the conditions that may exist and of the anatomical changes that may have taken place, as a result of an udder becoming "broken down" and pendulous. If, as it appears, an inherited weakness in the suspensory tissues, and excessive weight of the udder and its contents are two of the chief factors contributing to the breaking down of the udder, the selection of breeding stock that are known to have an inheritance for well attached udders, and more frequent milking of heavy producing cows, should be effective as preventive and remedial measures.

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